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The rainfall of depressions which move eastward across Scotland

by
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1. Introduction. Studies of the rainfall of depressions which move eastward over or near to the British Isles have already been reported in M.R.Ps. 748, 762 and 816. These previous investigations have dealt with depressions which passed north of Scotland, crossed England or moved eastward near the English Channel. The present paper is concerned with depressions which crossed Scotland and completes the study of the rainfall of all depressions which moved eastward near or over the British Isles in the ten years 1941 - 1950.

2. Method. The method followed that of the previous investigations. From the Daily and Monthly Weather Reports all occasions were selected from the period 1941 - 50 on which a depression (defined by a closed isobar) crossed Scotland with an eastward component of motion. 49 such depressions were noted.

Rainfall charts were drawn for the British Isles on the basis of the observations printed in the Daily Weather Report. The period covered by the chart was chosen to include all of the frontal rain from the depression; showers in the adjacent air masses were necessarily included and in some cases there was difficulty in separating the rain from that of preceding or following systems. However the main features of the rainfall distribution were rarely in doubt. Two of the rainfall charts covered a 60 hour period but the remainder included 48 hours or less, the majority including only 24 or 36 hours.

For each depression a 1000-500 mb thickness chart was constructed; this was drawn for a time chosen to present the thermal structure of the depression as it crossed the British Isles. Observations from the German Daily Weather Reports were used to extend the British charts for the war-period.

3. The average rainfall distribution. Fig. 1 shows the average rainfall distribution for the periods during which the depressions moved across Scotland. It is based on the average rainfall values shown on it, and in calculating these, values have been interpolated from individual rainfall charts for occasions for which observations were not available in the Daily Weather Report. Since the observations on which Fig. 2 is based were nearly all made on relatively low ground the chart does not adequately represent the rainfall of the hilly areas. However some average values for higher level stations in Scotland, Wales and Devon are given as an inset.

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The values for Princetown, Cray Reservoir (Breconshire) and Cwm Dyli near Snowdon are taken from the autographic records; those for Eskdalemuir and Dalwhinnie from the Daily Weather Report.

Fig. 1 shows a maximum of about 15 mm near to the average track of the depressions with rainfall values falling off more or less regularly to south and north. Rainfall in the west of the British Isles is greater than the east; the difference is more marked in the south. Considered in relation to the tracks of the depressions studied the average rainfall amount and pattern is very similar to that shown in M.R.Ps. 762 and 816 for depressions on tracks further south.

As would be expected the rainfall at the high-level stations in Wales and Devon is much greater than that at neighbouring stations on low ground. Eskdalemuir also receives more rain than other stations in South Scotland but the difference here is not so marked. In the previous reports also it was noted that the most marked orographic effect was found some distance to the south of the track of the depression where a deep westerly current was likely to be more persistent.

In order to present a clearer picture of the rainfall in relation to the track of the depression an estimate has been made of the average rainfall over areas centred 50, 150 and 250 miles north and south of the track of the depression. The resulting average profiles of rainfall are given in Fig. 2 for east and west coast districts separately. The curves for east and west coast districts are generally similar but confirm the greater rainfall of the west. The curves also are very similar to the profiles of rainfall for depressions crossing the British Isles further south as given in M.R.Ps. 762 and 816.

Fig. 3 shows the percentage of the 49 depressions which gave less than 0.1 mm of rain at stations in the British Isles.
The main features of the chart are:-

(a) At stations in Southern Scotland (i.e. near to the average track of the depressions) all of the depressions gave measurable rain.

(b) The number of cases without measurable rain increases southeastward and becomes 20% at about 300 miles from the general track of the centres.

(c) The distribution of "dry" cases is very similar to that accompanying depressions which move eastward between Scotland and the Faeroes although the proportion of dry cases is not so high. Over England and Wales the proportion of dry cases is much greater in the east than in the west.

(d) The difference between the frequency of dry cases at the high level stations and neighbouring stations on lower ground is not very great (see inset to Fig. 3).

Fig. 4 contains histograms of rainfall amounts for selected stations and shows the wide range of variation at individual stations among the rainfall of the various depressions which follow the selected track.

4. Characteristics of individual rainfall distributions. The rainfall patterns from individual depressions were very irregular. In the previous investigations a well defined band of heavier rainfall had frequently been noted along the track of the depression. This was less common for depressions crossing Scotland than for depressions following tracks further south and such a rainfall band was noted in association with only 14 out of the 49 depressions which crossed Scotland. Probably the irregular topography of Scotland has an effect in disturbing the regular organisation of the rainfall pattern. In the previous studies also it was found that a clearly defined rainfall band usually occurred with fast moving depressions in a pattern of thickness lines with little distortion. Neither the relation with the speed of the depression nor with the thickness pattern could be demonstrated for the depressions which crossed Scotland.

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5. Variation in rainfall amounts in relation to synoptic parameters. As a measure of the general rainfall in Scotland the average rainfall was calculated for two groups of six stations in and near Scotland. The correlation between the two groups was + 0.86 and it was assumed that the average of all 12 stations would give a reasonably representative measure of the rainfall activity of the depression in Scotland. As a similar measure of the "raininess" of the depressions over England the average rainfall of 6 stations in Wales and the southern half of England was used (viz Holyhead, Spurn Head, Plymouth, Boscombe Down, Mildenhall and Lympne). The correlation between the average rainfall of this group and that of the 12 Scottish stations was only + 0.43 and indicates that the rainfall from these depressions in the south of England is not closely related to that in Scotland.

The relation between the rainfall at both the Scottish and the English groups of stations was compared with various synoptic parameters. The central pressure of the depression was found to have only a small negative correlation (about -0.35) with the rainfall of both groups. The lowest pressure in the pressure trough in latitude 50°N is a much better guide to the rainfall in England and has a correlation of -0.60 with the rainfall at the English group of stations. A similar fairly high correlation is given in M.R.P. 748 in respect of depressions which pass between Scotland and the Faeroes.

There is very little correlation between the direction of motion of the depression or its speed and the rainfall in either Scotland or England. The relations with Scottish rainfall are insignificant but small negative correlations of about -0.25 and -0.4 are obtained with the rainfall at the English group of stations indicating that the depressions with a component of motion towards the south and those moving more quickly tend to give less rain.

Examination of the 1000-500 mb thickness patterns associated with the depressions gives no obvious relation between the rainfall amounts and the distribution of 1000-500 mb thickness. There is a slight tendency for the depressions with a strong thermal wind over the centre in the direction of motion to give less rain but the correlation between rainfall and thickness gradient normal to the direction of motion is numerically less than -0.2. Also there is a positive relation between thermal wind component towards the left of the track and the rainfall amount (correlation coefficient about + 0.35) for the Scottish group of stations indicating that depressions with a strong thermal trough behind the centre tend to give more rain than those with a less marked trough.

6. Conclusions. The average pattern of rainfall from depressions moving eastward across Scotland shows a maximum of about 15 mm near the track of the centres falling off to north and south to about half the central value at a distance of about 300 miles. In relation to the track of the depressions the average rainfall pattern is very similar to that for depressions moving eastward on other tracks near the British Isles, suggesting that orographic features are of only secondary importance in determining the rainfall distribution at stations on low ground. On the other hand there is a very great orographic increase in the rainfall amounts at high level stations south of the depression track compared with neighbouring low level stations.

There is a very great deal of variation between the rainfall patterns resulting from individual depressions and comparison of rainfall amounts with various synoptic parameters fails to bring out any relationships close enough to be of much value in forecasting. The rainfall amounts in Scotland are not closely related to those in England. Rainfall tends to be greater in association with the deeper depressions, but the depth of the pressure trough south of the centre is a better guide to the rainfall over England. The existence of a thermal trough behind the centre also tends to be associated with larger rainfall amounts.

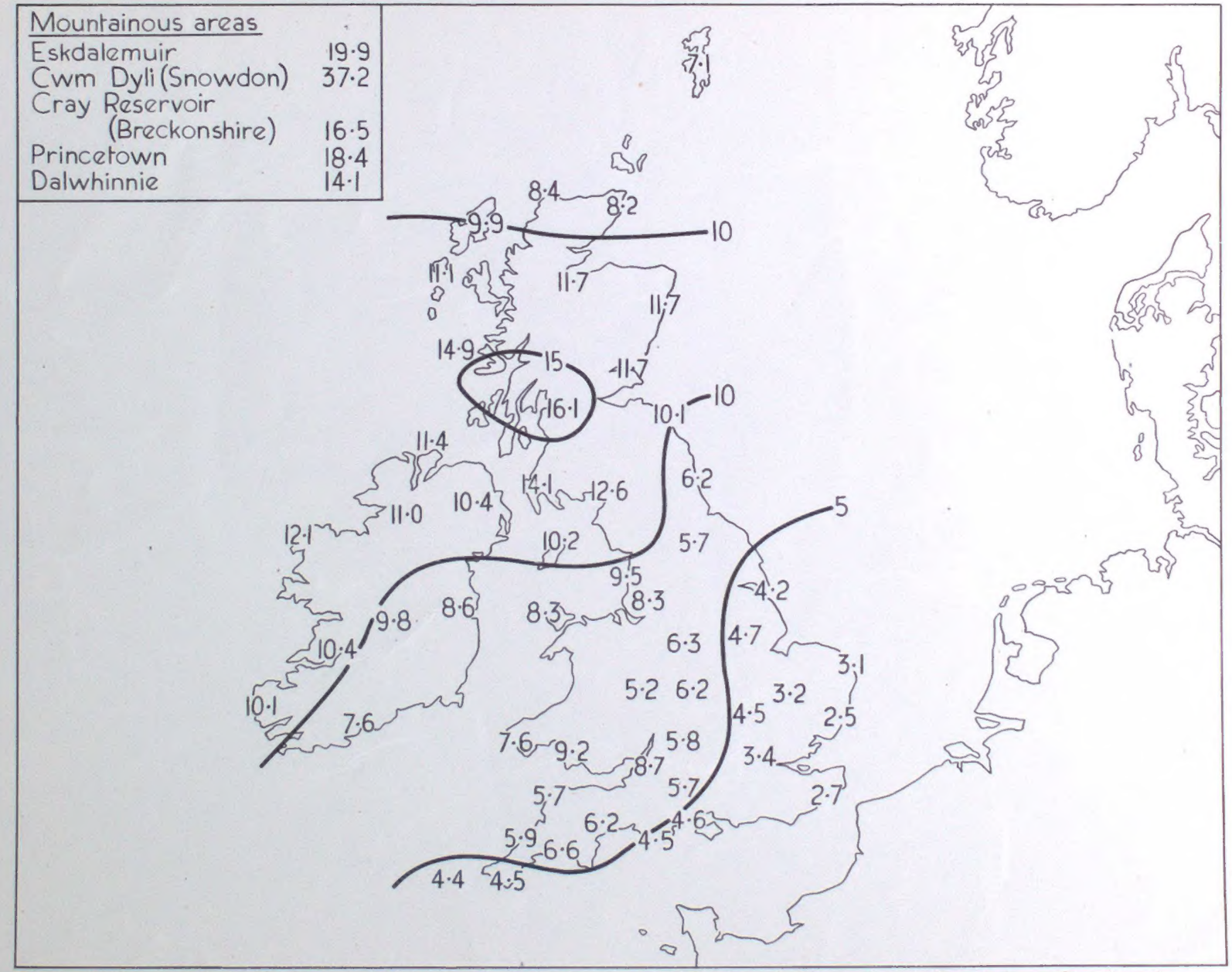

Fig.1 Average rainfall (m.m.) from depressions which moved eastward across Scotland — 49 cases — period 1941-1950

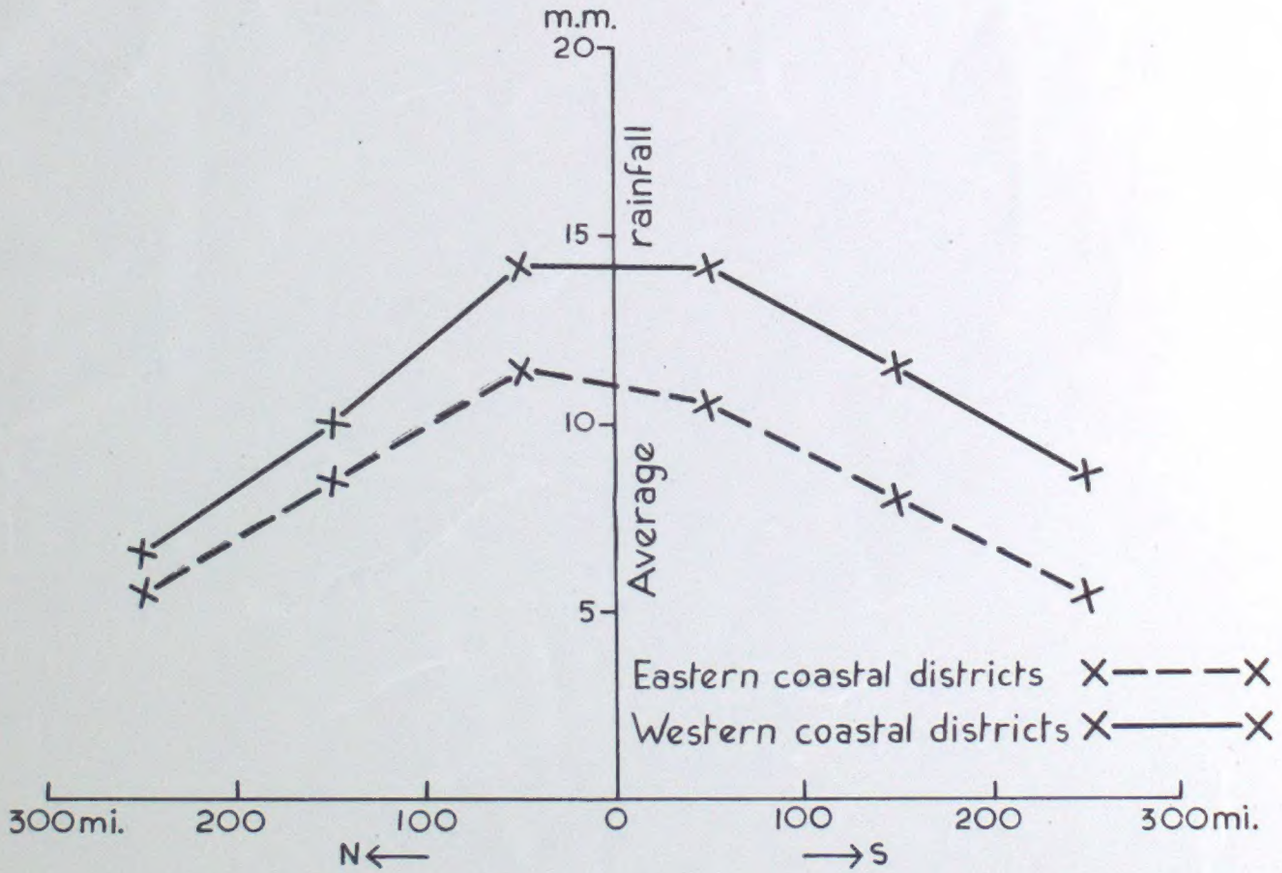

Fig. 2 Average profile of rainfall across the track of a depression moving eastward across Scotland

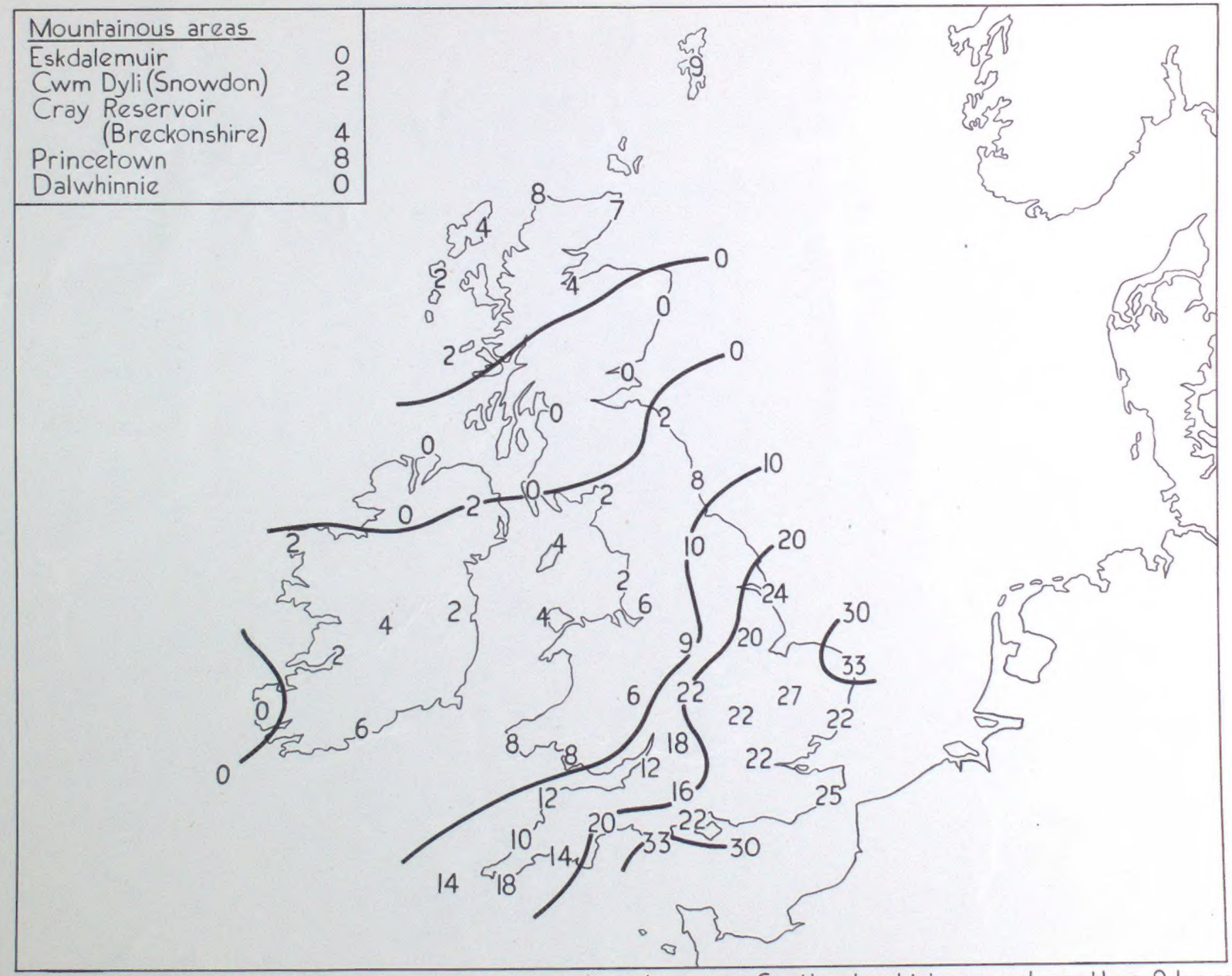

Fig. 3 Percentage of depressions moving eastward across Scotland which gave less than 0·1 m.m. of rain — 49 cases — period 1941–1950

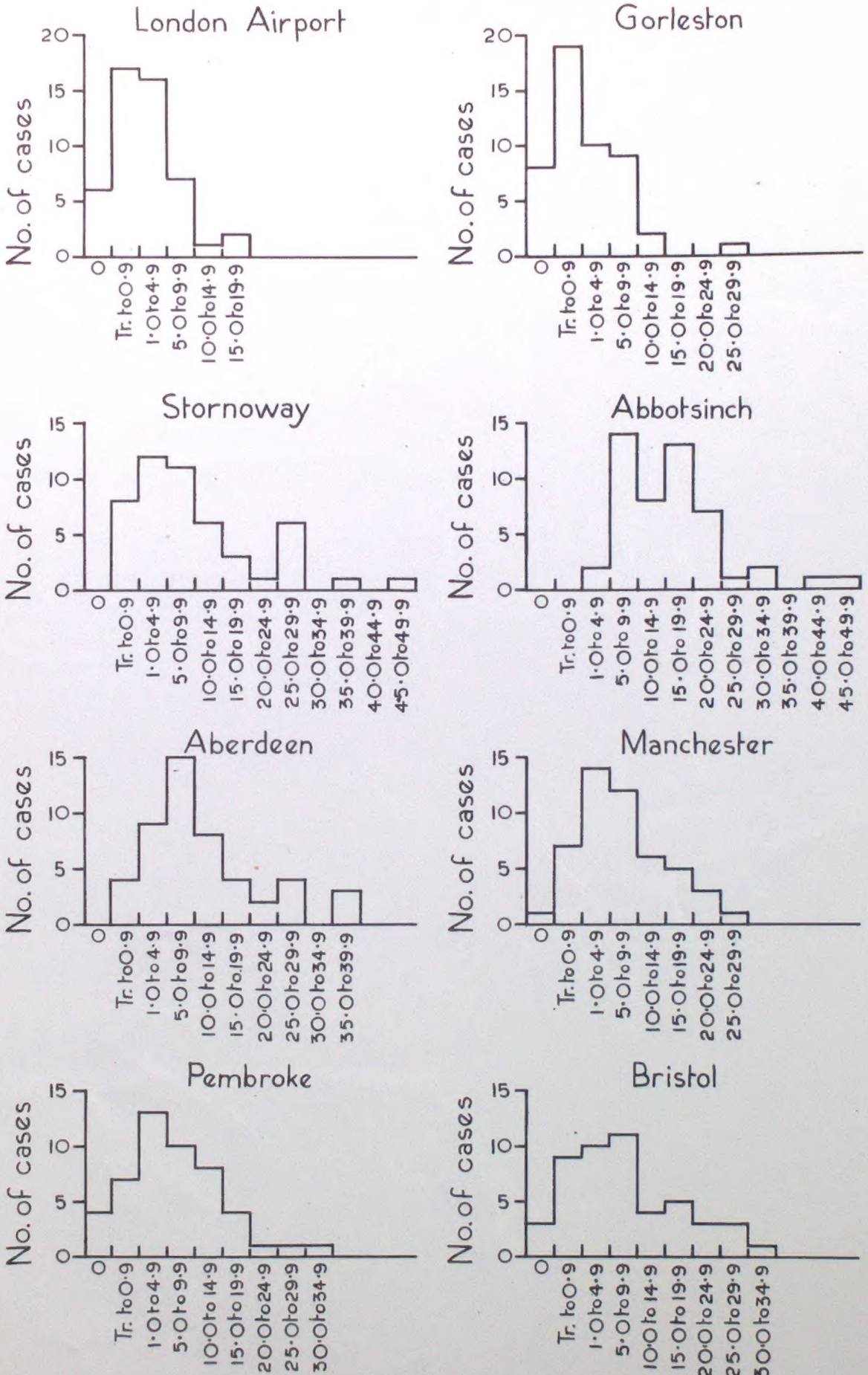

Fig. 4 Depressions which moved eastward across Scotland — 49 cases — period 1941–1950
Frequency diagrams of rainfall totals (m.m.) from individual depressions at selected stations